The Brown County, Texas, Tornado of May 9, 1997

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1. Introduction

The tornado has been defined as a violently rotating column of air pendant from a thunderstorm and in contact with the ground. Exactly where tornadogenesis occurs within a thunderstorm is a topic of much research in the meteorological community, most notably the Verification of the Origins of Rotation in Tornadoes EXperiment (VORTEX) (Wakimoto and Atkins, 1995). This paper will investigate Doppler radar trends associated with a tornado that occurred 22 km (14 nm) north-northwest of Brownwood, Texas, at 0730 UTC 9 May 1997. This tornado inflicted damage on the roof and structure of an off-duty weather observer's house. The tornado was rated as a category 1 on the Fujita tornado damage intensity scale. This tornado appears to fit into a class of tornadoes described by Brady and Szoke (1989) and Wakimoto and Wilson (1989) that form in the initial absence of a mid-level mesocyclone.

2. Synoptic pattern

The 0000 UTC 300 hPa pattern (Fig. 1) was characterized by a longwave ridge from the Great Basin to the southwest Canadian provinces. Further east, a longwave trough was centered over northern Lake Superior. A 25-30 m s^{-1} (50-60 kt) wind speed maximum extended from Southeast New Mexico into the base of the eastern U.S. longwave trough.

Analysis of the 0000 UTC 700 hPa pattern revealed pressure and thermal troughs from the northern Texas Panhandle to the Big Bend region of Texas. The thermal trough was defined by a 2-3^{o} C depression over West Texas (Fig. 2).

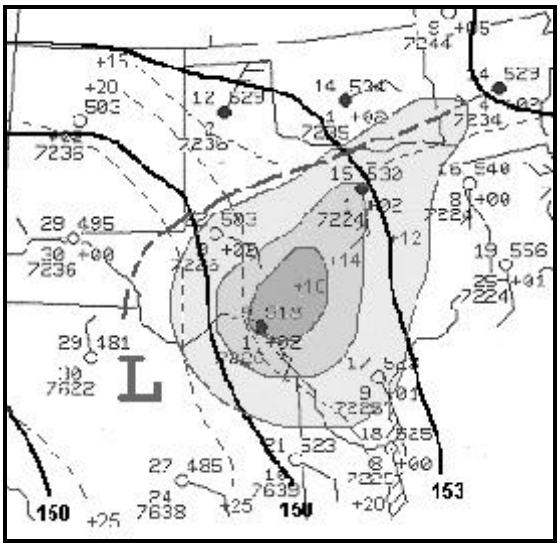

FIG. 3. 850 hPa analysis at 0000 UTC 9 May 1997. Solid lines depict geopotential heights in units of meters x 10. Shaded areas depict Isodrosotherms in units of degrees Celsius.

At 850 hPa (Fig. 3), an east-to-west oriented pressure trough extended from Southeast New Mexico, across at least North Texas and into Southeast Oklahoma. Dewpoints of 14° C or higher were noted from near Del Rio, Texas into North Central Texas.

3. Doppler radar data

Doppler radar data for this study were

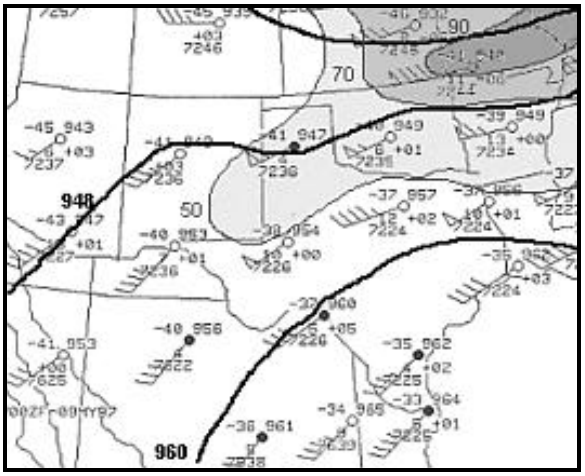

FIG.1. 300 hPa analysis at 0000 UTC 9 May 1997. Solid lines indicate goepotential heights in decameters. Isotachs (shaded areas) are shown in knots.

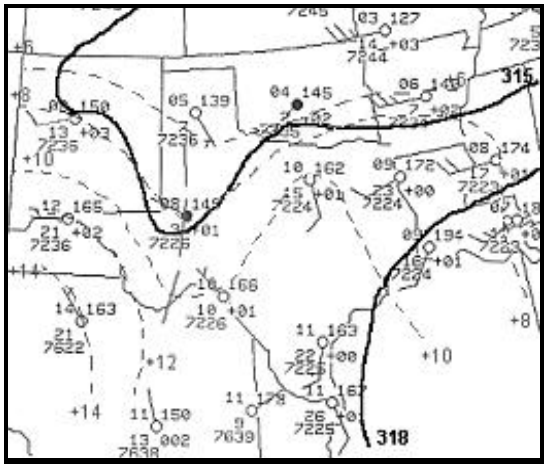

FIG. 2. 700 hPa analysis at 0000 UTC 9 May 1997. Solid lines indicate geopotential heights in decameters. Dashed lines indicate isotherms in units of degrees Celsius.

obtained from the Dyess Air Force Base (KDYX) WSR-88D Level IV Archive. At 0651 UTC (Fig. 4, upper left), two bow echos were evident over northeast Coleman County (center of each respective radar image) and to the northeast, in Eastland County. The leading edges of these bow-shaped thunderstorms intersected over northeast Coleman County, forming a line echo wave pattern. Storm-relative radial velocities at the 0.5° elevation exceeded 25 m s^{-1} (50 kts) (Fig. 4, upper right), producing cyclonic radial shear of 0.020-0.030 s^{-1} along the gust front in Coleman County. At 0651 UTC, maximum shear of 0.040 s^{-1} was reached in northeast Coleman County 4 nm south of the intersecting bow echoes. Straight line winds of 26 m s^{-1} (52 kt) were reported in the city of Coleman at 0712 UTC.

As the southern bow-shaped thunderstorm moved into western Brown County at 0711 UTC (Fig. 5), rotational shear values of 0.015-0.029 s^{-1} were indicated by the WSR-88D Storm Relative Motion (SRM) product along the storm's leading edge at the 0.5° and 1.5° elevations. At the 3.4° elevation, broad cyclonic convergence was evident at approximately 5.3 km (17,600 ft) AGL in east central Coleman County. This mid-level shear was centered 8 km (5 n mi) southwest of the maximum 0.5° shear in northwest Brown County. No mesocyclones were detected by the KDYX Mesocyclone Detection Algorithm through 0711 UTC.

By 0721 UTC, radial shear to 0.029 s^{-1} continued at the 0.5° and 1.5° elevations along the forward flank of the thunderstorm complex as it entered Brown County (Figs. 6 and 7).

The 0721 UTC SRM product revealed cyclonic divergence at the 6.2 ° elevation, approximately 10.7 km (35,000 ft) AGL (Fig. 8). Unfortunately, due to the Routine Product Set (RPS) list in use at the time, the 6.2° elevation SRM products were not available prior to 0721 UTC.

As strong low level cyclonic convergence became coupled with cyclonic divergence aloft, updraft development appeared to intensify along the gust front in north central Brown County. Base Reflectivity imagery from 0721 UTC indicates a 6.2° elevation reflectivity maximum 6.4 km (4 nm) west-northwest of the low-level circulation center (Fig. 9). By 0732 UTC, the 6.2° reflectivity maximum had increased in intensity to 55-59 dBZ as it became collocated with the 0.5° reflectivity gradient along the storm's forward flank.

The 0732 UTC SRM product revealed maximum gate-to-gate shear of 0.036 s^{-1} at the 0.5° elevation in the southwest portion of the WSR-88D-identified mesocyclone (Fig. 11). Storm top divergence of 40 m s^{-1} (80 kts) was evident directly above the low-level shear feature at the 10.0° elevation (14.5 km, 47.5 kft altitude).

The position of the upper-level reflectivity maximum (Fig. 10) and the position of storm top divergence maxima (Fig. 11) show that the low-level circulation had become collocated with a vigorous storm-scale updraft by 0732 UTC. This is about the time of tornado occurrence.

The WSR-88D Layer Composite Reflectivity Maximum (LRM) product revealed an increase in maximum reflectivity above 10.0 km (33,000 ft) MSL that commenced approximately 10 minutes prior to the reported 0730 UTC tornado touchdown (Fig. 12). This increase in maximum reflectivity occurred directly above the low level circulation center in north central Brown County.

4. Conclusions

This tornado was preceded by intense low-level circulation at the intersection of two outflow

boundaries up to 30 minutes prior to a radar-detected mid-level mesocyclone. Persistent vertical shear to 0.021 s^{-1} existed along the gust front in northeast Coleman County forty-five minutes prior to reported tornado touchdown. Studies conducted by the National Severe Storms Laboratory and the WSR-88D Operational Support Facility indicate that the probability of tornado occurrence within a twenty minute period approaches 30 percent when shear values reach 0.021 s^{-1} . When radial shear reaches 0.040 s^{-1}, the likelihood of tornado occurrence within a 20 minute period was found to be greater than 40 percent (Burgess, 1997).

This case emphasizes the need for interrogation of storm structure, as the position of the updraft over the low level shear maximum appeared to be the catalyst for tornadogenesis. The WSR-88D operator should recognize persistent, strong low-level shear as a precursor to a possible tornado, especially if cyclonic convergence intensifies along an otherwise linear boundary under a developing updraft.

A correct RPS list should be chosen to ensure the proper sets of elevation scans and volume products are available to the radar operator with each volume scan. This is especially important if the radar-operator interface is an Associated Principle User Processor (APUP), as potential narrowband load shedding places a limitation on the amount of products in the RPS list. The WSR-88D LRM product may provide a quick and useful indicator of reflectivity trends in the middle and upper reaches of the thunderstorm, even if higher elevation Base Reflectivity scans were not initially part of the RPS list.

5. Acknowledgments

The author wishes to thank Gregory E. Jackson, Science and Operations Officer, National Weather Service Office San Angelo, Texas for his suggestion to conduct this study and his guidance during preparation of the study.

6. References

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Burgess, D.W., 1997: Tornado Warning Guidance. Contained in a memo to all WSR-88D sites, OSF/OTB, Norman, OK, 28 pp.

Wakimoto, R. M., and N. T. Atkins, 1995: *Observations on the Origins of Rotation; The Newcastle Tornado during VORTEX 94*, Monthly Weather Review, 124, 384-407

Wakimoto, R. M., and J. W. Wilson, 1989: *Non-supercell Tornadoes*, Monthly Weather Review, 117, 1113-1140

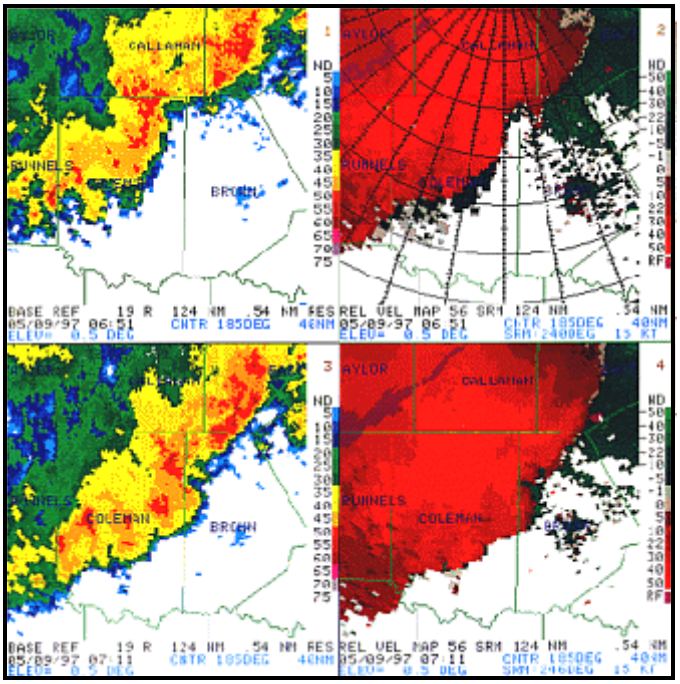

FIG. 4. Storm Relative Motion and Base Reflectivity Products at 0651 UTC (top) and 0711 UTC (bottom). Radar Data Acquisition Unit is approximately 65 km (41 n mi north of the bow echo intersection point at 0711 UTC.

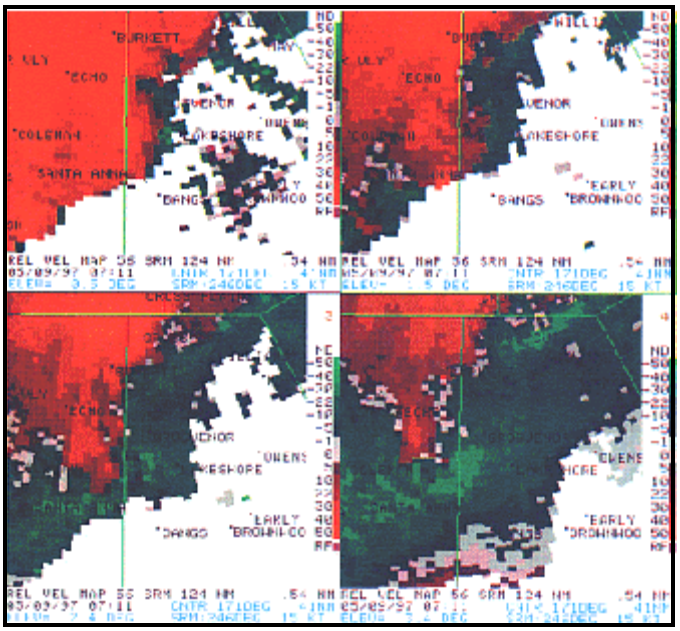

FIG. 5. Storm Relative Motion at 0711 UTC, 0.5º, 1.5º, 2.4º and 3.4º.

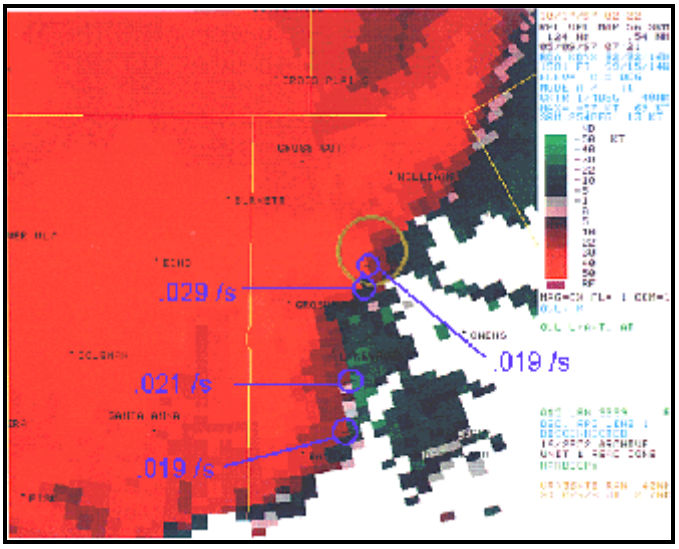

FIG. 6. Storm Relative Motion at 0721 UTC, 0.5º elevation.

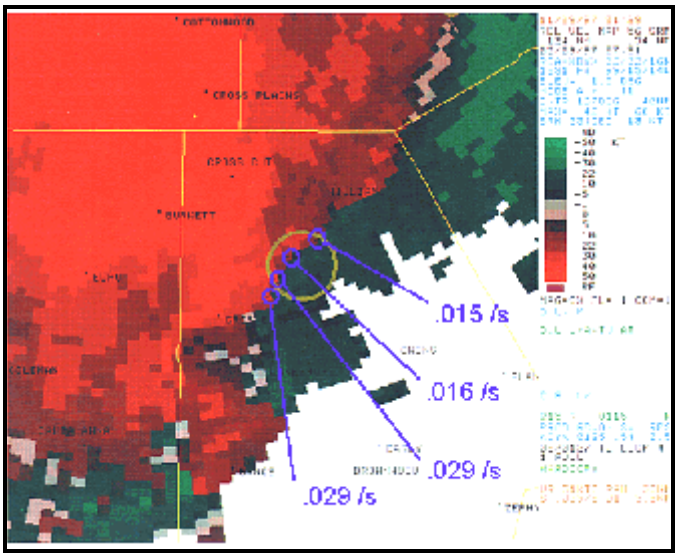

FIG. 7. Storm Relative Motion at 0721 UTC, 1.5º elevation.

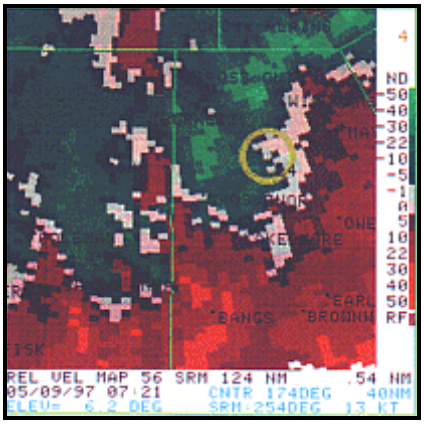

FIG. 8. Storm Relative Motion at 0721 UTC, 6.2º elevation.

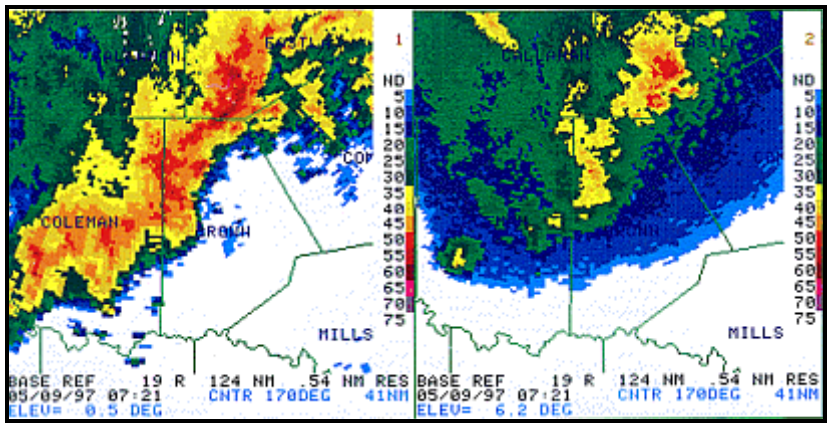

FIG. 9. Base Reflectivity at 0721 UTC, 0.5º and 6.2º elevation.

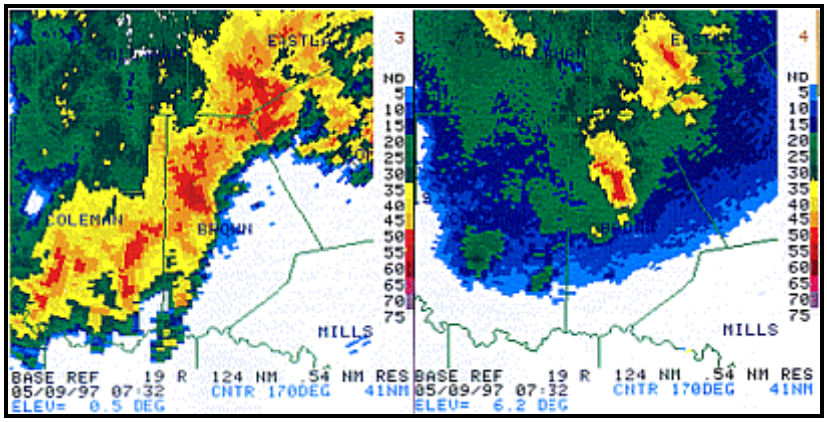

FIG. 10. Base Reflectivity at 0732 UTC, 0.5º and 6.2º elevation.

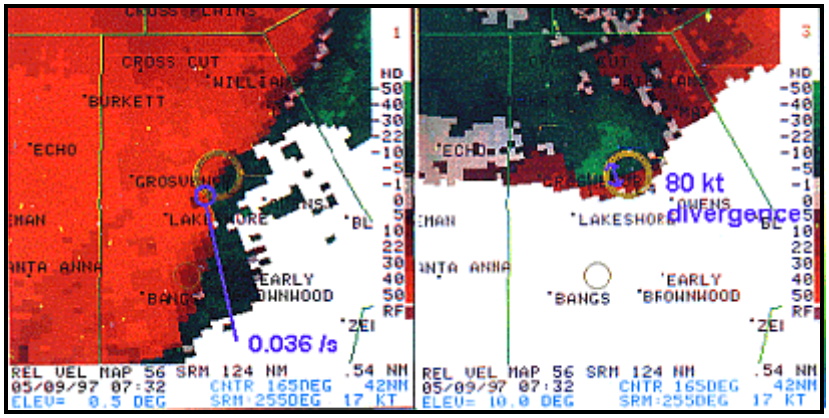

FIG. 11. Storm Relative Velocity at 0732 UTC, 0.5º and 10.0º elevations.

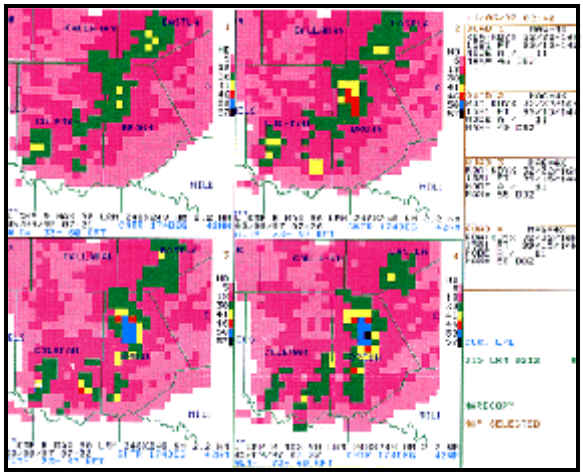

FIG. 12. Layer Composite Reflectivity Maximum 10.0-18.2 km (33-60 kft) from 0721 UTC to 0737 UTC.